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Provenance analysis and thermo-dynamic studies of multi-type Holocene duricrusts (1700 BC) in the Sua Salt Pan, NE Botswana

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ABSTRACT

Multi-type duricrusts, composed of silcretes, calcretes, halcretes and sulcretes developed during the Holocene at the northern rim of the Sua Salt Pan, NE Botswana. They were investigated for their light (quartz/chalcedony, feldspar, analcime, clinoptilolite, calcite, kaolinite/halloysite, illite–smectite mixed-layers, halite) and heavy minerals (baryte, clinozoisite–epidote s.s.s., amphibole, corundum, tourmaline, ilmenite, rutile, sphene, kyanite, andalusite, staurolite, garnet, zircon, apatite, monazite, cassiterite, garnet, biotite) using petrographic microscopy, X-ray fluorescence and diffraction analyses, radio-carbon dating, scanning electron microscopy equipped with an EDX-system, cation exchange capacity and infrared spectroscopy. Detrital minerals predominantly derived from the erosion of rocks belonging to the Archaean Basement Complex, the Stormberg Volcanites and the Kalahari sediments. Of particular interest to exploration geologists, geikielite-enriched ilmenite fragments are a hint to kimberlitic pipes. Biodetritus was derived from invertebrates and from vertebrates (fish bones?). A man-made impact on the heavy mineral suite has to be invoked from small fragments of cassiterite fragments that derived from processing of sulfidic and pegmatitic Sn-bearing ore. In the salt-pan-derived duricrusts mainly the aeolian and to a lesser degree fluvial inputs were responsible for the concentration of clasts in these multi-type duricrusts. Moreover, their variegated mineralogy enables us to constrain the physical–chemical regime, prevalently as to the pH and the chemical composition of the major constituents. All duricrusts developed in a self-sufficient chemically closed system where quartz and feldspar provided the elements Si, Na, K, Ca, and Ba to produce the encrustations. The spatial and temporal trend in the Sua Salt Pan rim encrustations may be described as follows: (1) sulcrete–silcretes, (2) silcretes with kaolinite-group minerals towards more recent stages at the rim and smectite-illite mixed-layers and clinoptilolite towards the basin center, (3) calcretes with analcite towards the basin center, (4) halcretes (and soda ash at a more central position). In the sulcrete–silcrete facies the pH decreases from pH 14 down to 4. In the calcretes and halcretes it increases from pH 8 to pH > 13. marking a chemical hiatus between stages 1 plus 2 and stages 3 plus 4. Mineral assemblages forming more basinward tend to have derived from more alkaline fluids than those near the edge of the salt pan.

1. Introduction

One of the largest salt pans in the world, the Makgadikgadi Pan system, extends across the Kalahari Desert southeast of the Okavango Delta in northern Botswana (Fig. 1a). It is a flat basin with separated salt pans. The largest of the pans of the Makgadikgadi Pan system is the Sua Salt Pan (SSP), which also accommodates the deepest part of the Pan system. SSP interfingers with sandy to silty patches of dry savannah (Cooke, 1980; Helgren, 1984). It is the presence of silcrete–calcrete–sulcrete–halcrete intergraded deposits that makes the SSP very attractive especially for mineralogists and sediment petrographers because they allow them an insight into very different physical–chemical regimes closely related to each other in time and space. Several studies have focused on these duricrusts and their metalliferous members (e.g., Semenunik and Meaghar, 1981; Goudie and Pye, 1983; Summerfield, 1983a,b; Wilson, 1983; Wright and Tucker, 1991; Nash and Shaw, 1998; Tandon and Kumar, 1999; Alonso-Zarzaa and Arenas, 2004; Tandon and Narayan, 2006; Dill et al., 2013). Research on (paleo)-climatic regime and environmental aspects have given only general results for large areas with the aid of whole-rock lithochemical and isotope studies (Nash et al., 1994). Chemical

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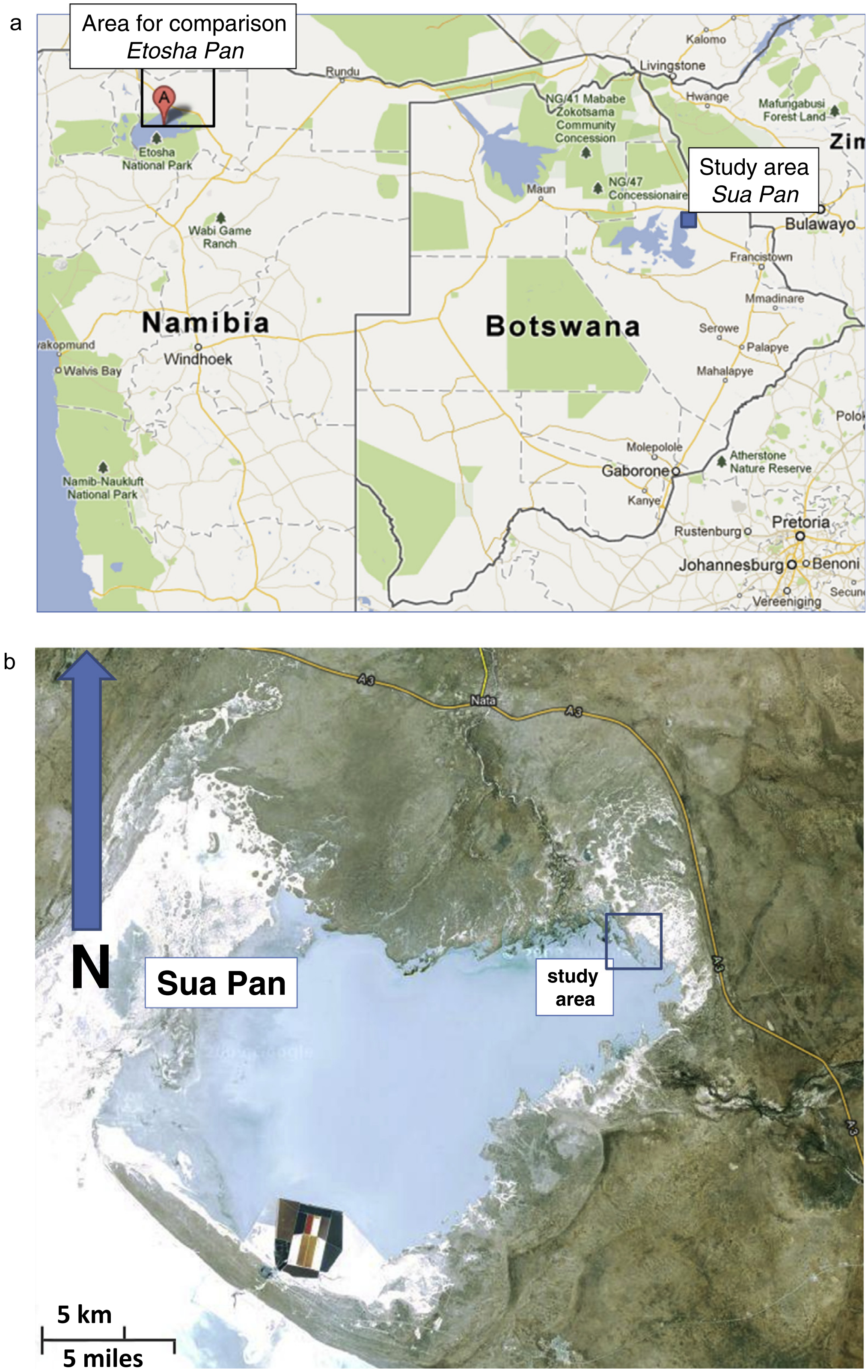

Fig. 1. Topographic and geologic setting of the Sua Pan. (a) The topographic position of the Sua Pan and Etosha Pan in Namibia and Botswana. (b) Satellite image of the Sua Pan. The white rim is evaporates, which are exploited at the southern edge (colored, elongated areas) (both topographic sources from Google Maps, 2013). The blue frame in Fig. 1b denotes the blue square in Fig. 1a. (c) Geological setting of the Sua Pan (geology modified after Mortimer (1984) and the Geological Survey of Botswana (2000)). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

studies by Ringrose et al. (2009) gave insight into the paleoclimatic conditions of the Makgadikgadi Pans throughout the last 90,000 years. During this time interval the SSP duricrusts were formed. Geomorphologists, such as Shaw and Thomas (1992) and Cooke and Verstappen (1984), placed more emphasis on the complete pan system.